April 11th, 2022
U.S. Department of Transportation, Docket Operations
West Building Ground Floor, Room W12-140
1200 New Jersey Avenue, SE
Washington, DC 20590

Re: Request for Exemption under Section 333 of the FAA Modernization and Reform Act, Subsection (f) of 49 U.S.C. § 44807, and 14 CFR Part 11 from 14 CFR 91.119(c); 91.121; 91.151(b); 91.405(a); 91.407(a)(1); 91.409(a)(1) and (2); 91.417(a) and (b) for UAS operations over 55 pounds.

INTRODUCTION

Pursuant to Section 333 of the FAA Modernization and Reform Act of 2012 (FMRA), Subsection (f) of 49 U.S.C. § 44701, and 14 CFR Part 11, the University of California at Berkeley (hereafter known as the "Petitioner"), respectfully requests approval and exemptions from this list of Code of Federal Regulations. The purpose for this request is to enable U.C. Berkeley to operate their E500 unmanned aircraft over 55 pounds to collect gravitational measurements in rural and remote areas. E500 operations will be conducted within and under the conditions outlined herein, or as may be established by the FAA, as required by Section 333 and 44701 requirements.

As described more fully below, the requested exemption would permit the operation of the E500 under controlled conditions in airspace that is: 1) limited; 2) predetermined; 3) controlled access. Grant of the requested exemption is in the public interest based upon the concise direction expressed within Section 333 of the FMRA; the added authority granted by the Act, as amended; an equivalent level of safety regarding flight operations as expressed herein, to achieve significant scientific advancement by utilizing UAS to perform gravitational measurements.

The Petitioner respectfully requests that the FAA grant the requested exemption without delay. Petitioner will operate the E500 while keeping the documents required by the regulations at the ground control station and immediately accessible to the pilot in command (PIC) and by modification of the required markings (registration number N133CS) of the E500 to be displayed on the fuselage.

The E500 was designed, built, and flight tested by Event 38. An independent safety review has been conducted by Airspace Consulting. Airspace Consulting assisted with preparation of the unmanned aircraft flight manual, flight operations manual, and operational risk assessment.

The primary contact for this petition is:

Francis A. Ketcham
Commercial Aviation Specialist
Institute of Transportation Studies
109 McLaughlin Hall MC 1720
Berkeley CA 94720-1720
Email: fketcham@berkeley.edu
Telephone: (415) 999-7830

In support of this Petition for Exemption, the following confidential documents will be submitted on behalf of the Petitioner:

UAS Operations Manual
E500 Aircraft Flight Manual
Operational Risk Assessment
E500 Flight Test Data

These documents will be submitted on a confidential basis under separate cover, pursuant to 14 CFR § 11.35(b), as the documents contain confidential commercial and proprietary information that the Petitioner has not and will not share with others. The information contained in this material is not generally available to the public and is protected from release under the Freedom of Information Act, 5 U.S.C. § 552 *et seq*.

UNMANNED AIRCRAFT SYSTEM

The E500 is an electric multirotor unmanned aircraft in the X-8 configuration. The E500 is designed specifically for carrying a gravitometer designed by the U.C. Berkeley physics department. The E500 aircraft was designed by Event 38 to be a safe and reliable heavy-lift platform.

The dimensions and physical characteristics of the E500 are as follows:

Manufacturer:	Event 38
Flight Controller:	Pixhawk 2.1 Orange Cube
Motors:	T-Motor U15XL KV38 Brushless Motors
Propellers	T-Motor NS57x22 Carbon Fiber Propellers
Utilization:	Scientific Data Collection: Gravity Measurement Device
Airframe Diameter:	191 inches
Airframe Height:	85 inches
Max Takeoff Weight:	630 pounds
FAA Registration Number:	N133CS

COMPONENTS AND SAFETY SYSTEMS

Pixhawk Flight Controller – The Pixhawk 2.1 Orange Cube is a professional autopilot developed by world-class developers from industry and academia. It has multiple types of fail-safe systems that are integrated on the E500.

Mission Planner – Ground Control Software that provides full flight control and configuration of the UAS. Mission Planner features a complete and fully customizable control station for MAVLink based unmanned aircraft.

Battery Packs – Each motor pack consists of six 4S24P LiPo batteries. The E500 uses four of these battery packs, with a total of 24 batteries. Each of the 24 batteries are labeled with serial numbers and were tested by running a simulated 25-minute flight.

Propulsion System – The propulsion system consists of eight T-Motor U15XL KV38 brushless motors in an X-8 configuration. Each of the four motor sets is powered by six 4S12P LiPo batteries providing up to 100.8V. The propellers used are the T-Motor NS57x22 inch propellers.

Redundant Power Plant System – The aircrafts power delivery system was designed such that if one battery fails in flight, the failure is spread to 2 motors on different arms. This allows the remaining operating motors and battery to continue to provide thrust on all 4 arms, allowing the aircraft to maintain orientation and, depending on the state of charge, make a controlled landing.

Command and Control (C2) – The PIC will control the E500 through a Futaba T6K Transmitter fitted with a 915MHz Radio Modem Receiver from DragonLink. The ground station will connect to the aircraft using an encrypted RFD900X telemetry module from RFDesign. If the control link is lost at any time during flight, the aircraft will switch to RTL (Return to Launch) mode, returning to the home location, landing, and then disarming. In the event the telemetry link is lost during flight, the flight controller will again switch to RTL mode and land autonomously.

MAVLink - Micro Air Vehicle Communication Protocol is utilized for communications between the flight controller and ground control station.

Flight Termination System (FTS) - A flight termination switch allows the pilot in command to instantly stop motors and force grounding of the aircraft in the event of an emergency.

Geofencing - The Pixhawk Orange Cube flight controller is given GPS coordinates of a boundary that it must stay within, keeping the E500 from leaving the pre-determined and defined operations area. When enabled, the E500 can reach the perimeter, but not fly past or through the boundary. Manual or automatic inputs commanding the E500 to break the geofence are rejected.

Redundant Sensors – The Pixhawk Orange Cube flight controller is equipped with redundant microelectromechanical sensors (MEMS). If the primary MEMS experience a failure, secondary or tertiary sensors will automatically take over as a failsafe to ensure accurate positioning and navigation is maintained. Any failure generates an alert to the ground control station.

Flight Data Recorder – The flight controller records all operator control input, GPS location information, vibration, battery voltage and all other critical telemetry data. The entire flight track can be replayed after the flight for training and troubleshooting. All flight data is automatically saved both on the E500 and the ground control station.

Safety parameters - Maximum altitude, distance from launch, horizontal speed and vertical speed parameters are set in the flight controller. These parameters provide an additional backup to the geofence and operate in the same way, preventing flight outside the allowable flight area.

Mechanical System/Checks – All mechanical hardware, joints, and welds are checked prior to flight according to a checklist. All hardware is torqued to spec and has torque stripe to indicate if any connections have become loose. For certain removable connections, Loctite Threadlocker Blue 242 is used.

Operational Analysis and Flight Testing – Prior to flight each of the motors was mounted to a test stand and powered to full throttle with the propeller facing the opposite direction for individual initial testing. Following the mounting of the motors to the frame, each set of coaxial motors was powered to test the effects of prop wash. The E500 has operated successfully inside the manufacturers lab and the aircraft performed well with no loss of telemetry, no issues with stability, or control and handling. Performance of all safety features work as designed.

PILOT IN COMMAND

Francis A. Ketcham will serve as Pilot in Command
He is an FAA licensed Pilot and holds the following Qualifications and Ratings:
Airline Transport Pilot
Commercial Single Engine Sea, Single Engine Land, Glider
Type Ratings: Airbus A320/A330/A350
Advanced Ground instructor
Flight Engineer - Turbojet
Aircraft Dispatcher
Builder of Experimental Vans RV-14A Aircraft N715BJ and holds Repairman Certificate
Remote Pilot

Mr. Ketcham has thousands of hours conducting Pilot in Command (PIC) commercial flight operations as well as extensive experience in UAS flight operations. Mr. Ketcham has well over 20 years of experience as a professional pilot. He has also served as a Commercial Aviation Specialist/Aviation Subject Matter Expert (SME) at University of California, Berkeley since 2008 in the School of Engineering. He has extensive experience with FAA Regulations Part 61, 91, 107, 135 and 121.

In addition to Pilot in Command duties Mr. Ketcham was integral in the design and development of the E500. He worked very closely with the manufacturer to oversee all phases of E500 development and will serve as Director of Flight Operations and Safety.

STATUTORY CRITERIA PROVIDED IN SECTION 333

Equivalent level of safety

The E500 carries neither a pilot nor passenger, carries no explosive materials or flammable liquid fuels, and operates exclusively within a secured area in remote and rural areas. Unlike other civil aircraft, operations under this exemption will be tightly controlled and monitored by both the operator, pursuant to the criteria in the operator’s manual, and under the requirements and in compliance with local public safety requirements, to provide security for the area of operation in remote and rural areas. The gravitational measurement device is mounted to the E500 and operated independently of aircraft systems.

The Federal Aviation Act (49 U.S.C.§ 44701 (f)) and Section 333 of the Reform Act both authorize the FAA to exempt aircraft from the requirement for an airworthiness certificate, upon consideration of the size, weight, speed, operational capability, and proximity to airports and populated areas. In all cases, an analysis of these criteria demonstrates that an unmanned aircraft operated without an airworthiness certificate, in the restricted environment and under the conditions proposed will be at least as safe, or safer, than a conventional aircraft (fixed-wing or rotorcraft) operating with an airworthiness certificate without the restrictions and conditions proposed.

As there will be no airworthiness certificate issued for the unmanned aircraft, and no FAA regulatory standard will exist for determining airworthiness of the unmanned aircraft, the requirements contained in the operator's manual for maintenance and use of safety check lists prior to each flight, will provide an equivalent level of safety.

Since there is no ability or place to carry certification and registration documents on the unmanned aircraft, an equivalent level of safety will be achieved by keeping these documents at the ground control station. Given the size of the unmanned aircraft, the FAA registration number will be displayed on the airframe in as large a font as possible.

Regulations from which the exemption is requested:

- 14 CFR § 91.119(c)
- 14 CFR § 91.121
- 14 CFR § 91.151(b)
- 14 CFR § 91.405(a)
- 14 CFR § 91.407(a)(1)
- 14 CFR § 91.409(a)(1) and (2)
- 14 CFR § 91.417(a) and (b)

14 CFR § 91.119(c): Minimum Safe Altitudes

Section 91.119 establishes safe altitudes for operation of civil aircraft. Section 91.119(d) allows helicopters to be operated at less than the minimums prescribed, provided the person operating the helicopter complies with any route or altitudes prescribed for helicopters by the FAA. Since this exemption is for an unmanned aircraft that is a rotorcraft and the exemption requests authority to operate at altitudes up to 400 AGL, an exemption may be needed to allow such operations. As set forth herein, except for the limited conditions stated in the operating manual, the unmanned aircraft will never operate higher than 200 AGL to collect accurate measurements from the gravitometer.

The equivalent level of safety will be achieved given the size, weight, speed of the unmanned aircraft as well as the location where it is operated. Compared to flight operations with aircraft or rotorcraft weighing far more than 630 pounds and the lack of flammable fuel, any risk associated with these operations is far less than those presently presented with conventional aircraft operating at or below 500 AGL. In addition, the extremely low-altitude operations of the unmanned aircraft will ensure separation between them and the operations of conventional aircraft that must comply with Section 91.119.

14 CFR § 91.121: Altimeter Settings

This regulation requires each person operating an aircraft to maintain cruising altitude by reference to an altimeter that is set "...to the elevation of the departure airport or an appropriate altimeter setting available before departure." As the E500 will not have a barometric altimeter, but instead a GPS altitude read out, an exemption from this regulation may be needed. An equivalent level of safety will be achieved by the operator, pursuant to the operations manual and safety check list, confirming the altitude of the launch site shown on the GPS altitude indicator before flight.

14 CFR § 91.151(b): Fuel Requirements for Flight in VFR Conditions

Section 91.151(b) states that "No person may begin a flight in a rotorcraft under VFR conditions unless (considering wind and forecast weather conditions) there is enough fuel to fly to the first point of intended landing and, assuming normal cruising speed, to fly after that for at least 20 minutes.

The battery powering the E500 provides approximately 25 minutes of powered flight. In order to meet the 20-minute reserve requirement in 14 C.F.R. § 91.151(b), flights would not be possible. Given the limitations on the E500 proposed flight area and the location of its proposed operations within a predetermined area, a reduced time frame for flight in daylight VFR conditions is required.

Petitioner proposes that an exemption from 14 CFR § 91.151(b) falls within the scope of prior exemptions. See Exemption 10673 (allowing Lockheed Martin Corporation to operate without compliance with FAR 91.151(a)). Operating the E500 in a tightly controlled area where non-participating persons will be more than 500 feet away, with less than 20 minutes of reserve fuel, does not engender the type of risks that Section 91.151(b) was intended to alleviate given the size and speed of the unmanned aircraft.

Applicant proposes that an equivalent level of safety can be achieved by requiring flights to have at least a 25% reserve of battery power. This restriction would be more than adequate to return the E500 to its planned landing zone from anywhere in its limited operating area. Similar exemptions have been granted to other operations, including Exemptions 2689F, 5745, 10673, and 10808

14 CFR § 91.405(a); § 407(a) (1); § 409(a)(2); § 417(a) and (b): Maintenance Inspections

These regulations require that an aircraft operator or owner "shall have that aircraft inspected as prescribed in subpart E of this part and shall between required inspections, except as provided in paragraph (c) of this section, have discrepancies repaired as prescribed in part 43 of this chapter…" and others shall inspect or maintain the aircraft in compliance with Part 43.

Given that these sections and Part 43 apply only to aircraft with an airworthiness certificate, these sections will not apply to the applicant. An equivalent level of safety will be achieved because the E500 is limited in size and will only operate in restricted areas for limited periods of time. If mechanical issues arise the E500 can land immediately since it will be operating from no higher than 400 feet AGL. As provided in the operations manual, the PIC will ensure that the E500 is in a safe condition prior to initiating flight, will perform required maintenance, and will keep a log of any maintenance performed. Moreover, the operator is the person most familiar with the aircraft and best suited to maintain the aircraft in an airworthy condition to provide the equivalent level of safety.

PUBLIC INTEREST

The ability to make precise gravity gradient measurements in previously inaccessible environments allows for sub-terrestrial cartography on a new level. The use of an unmanned aircraft below 200 feet AGL provides the ability for measurements that would be costly and impractical for helicopters. Additionally, conventional helicopters weigh thousands of pounds more than the E500 and carry flammable fuels that are not carried by electric unmanned aircraft.

FEDERAL REGISTER SUMMARY

Pursuant to Section 333 of the FAA Modernization and Reform Act of 2012, 49 U.S.C. § 44701(f), and 14 C.F.R. Part 11, the following summary is provided for publication in the FEDERAL REGISTER, should it be determined that publication is needed:

Petitioner seeks an exemption from the following rules in Title 14 of the Code of Federal Regulations: 91.7(a), 91.119(c), 91.121, 91.151(b), 91.405(a), 91.407(a)(1), 91.409(a)(1) and (2), 91.417(a) and (b).

The University of California at Berkeley (UC Berkeley) requests an exemption to operate their E500 unmanned aircraft system weighing over 55 pounds to measure variations in the earth's gravitational field for scientific research. This work will be conducted by the U.C. Berkeley Physics Department funded by the Department of Naval Research.

CONCLUSION

For the foregoing reasons, University of California at Berkeley respectfully requests that the FAA grant this Petition for Exemption. Should you have any questions, or if you need additional information to support the UC Berkeley petition, please do not hesitate to contact the undersigned.

Respectfully Submitted,

Francis A. Ketcham
Commercial Aviation Specialist
University of California at Berkeley